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Measurement of some Electrical Components by using a Single A.C. Bridge.

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Abstract: *Some useful electrical components like resistance, capacitor, self inductance and also mutual-inductance can be measured easily and accurately by different experiments. But experimentally to measure all these components at a time, no single method or apparatus is easily available, different methods are used to measure different components. In this experimental study, a new method (A.C Bridge) is developed to measure all the above mentioned components simultaneously and also accurately. The proposed method is nothing but a modified form of the existing bridge and some mathematical deductions are applied for the measurement of these components.*

Keywords: *Bridge, Components, Electrical, Mutual inductance, Self inductances.*

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I. Introduction

In an electrical as well as an electronic circuit, the roles of resistance, capacitor, self inductor and mutual inductance are very important because on the values of these components, circuits are made for the various purposes. Hence the accurate values of the electrical/electronic components are essential and different well known procedures are available to measure the components. Generally to get the experimental values of these components, different experimental methods are used for different components. The simplest way to measure the moderate value of resistance is by using the principle of wheat-stone bridge with D.C source. But for the measurement of the rest components, wheat-stone bridge principle may be applied but using A.C source. [1-2] For the measurement of unknown resistance, depending the order of the value of resistance (low to moderate values) different experimental methods are commonly used like fall of potential drop method, Meter bridge method, Carey-Foster's bridge methods etc. etc. but for all these processes, wheat-stone bridge principle is used. Discharge of a capacitor through ballistic galvanometer is applied specially for the measurement of resistance in mega-ohms order. The special feature of all the methods is, always used D.C source. For the measurement of capacitance, both D.C as well as A.C can be used. D.C power source is used at the time of measurement of capacity of the capacitance by ballistic galvanometer and using A.C source, different methods like by the study of CR circuit and Wien's parallel bridge are employed. For the measurement of inductance (co-efficient of self inductance) Anderson's bridge, Maxwell's L/C and Owen's bridge are generally used [1-4]. In case of Mutual inductance between two coils, ballistic galvanometer can be used with D.C. power supply and with the process, the co-efficient of mutual inductance can be measured, in addition to that various values of it also be measured for relative orientations of the two coils and another bridge called Campbell bridge, which is modified form of Carey Foster bridge is also used with A.C power source. But any particular methods which are mentioned earlier are not suitable for the measurement of all the electrical components simultaneously or one by one, using the same circuit (method).So different methods are employed for different components [3-6]. Hence the present study would be a try to introduce a single circuit for the measurement of all components simultaneously. The method is nothing but a modified form of an A.C bridge using basically a wheat-stone bridge, connecting different components in different ways of the four arms of the bridge. In the present study modified form of a common A.C bridge is introduced to measure all the components. The main principle of the proposed bridge is to achieve the electrical balance condition by changing other parameters except the measurable component and the achieved condition is independent of the frequency of the A.C source. Though the result of the unknown component is in terms of the other components but out of the three if any two when known the other unknown components can be determined accurately. This method is quite simple in construction and easy to construct either by using breadboard or using A.C bridge kit in laboratory. To measure a wide range of unknown component the values of the known components are to be used accordingly as the value of the unknown component relates with the values of the other components, which is achieved from the magnitude and phase balance after making the bridge highly sensitive. Even though for the measurement of very high or very low unknown component, the bridge is not as suitable as for the measurements of moderates values are. Accuracy of the obtained values of the components increases with the increase of the purity of the known components.

II. Experimental Set-Up And Theory

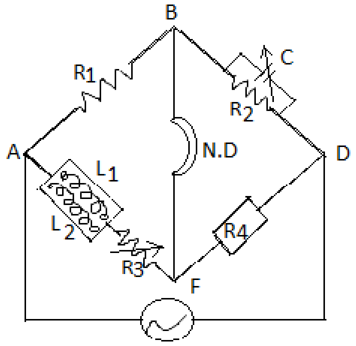

Fig.1 A.C Bridge

The proposed bridge for the simultaneous measurement of electrical components is shown in figure 1. It is basically a wheat-stone bridge using A.C source. AB, BD, DF, and AF are the four arms of the bridge. R_1, a resistance connected in the AB arm. BD arm connected with the parallel combination of R_2 and capacitance C. $R_{4,}$ variable resistance is inserted in the DF arm and L_1 and L_2 are two inductances separately placed and these may be connected separately or in series or parallel with the R_3 in the AF arm of the bridge. Null detector is connected with the points B and F to detect the balance condition. Instead of using a null detector head phone may be used. A.C source with moderate single frequency is used and connected with the points A and D. Actually single frequency generator is suitable to use because the values of the circuit components sometimes depends on the frequency. To operate the bridge, at first one inductor out of the two (Say L_1) is connected in series with R_3 (variable) and R_2 is fixed (~100 ohms) and two resistance boxes (0-10000 ohms) are used as R_1 and R_4 (instead of using resistance boxes, two resistance, 10k pot may be used). Adjusting the resistances $R_{1,}$ R_3 and R_4 the potentials of the ends B and F are to be made same. Hence the null detector showed minimum reading. At that time magnitude balanced is achieved. Now adjusting the capacitor once again further minimum reading of the detector may be achieved, which is called the phase balance of the bridge. So the balance condition is, $\frac{Z_1}{Z_2} = \frac{Z_3}{Z_4}$ ---- (1) where $Z_1 = R_1$ and Z_2 is the resultant impedance of the parallel combination of R_2 and C i.e. $\frac{1}{Z_2} = \frac{1}{R_2} + \frac{1}{1/jwC} = \frac{1}{R_2} + jwC$, $Z_3 = R_3 + jwL_1$ and $Z_4 = R_4$

Putting these values in equation (1)

$$R_1\left(\frac{1}{R_2} + jwC\right) = \frac{R_3 + jwL_1}{R_4},$$

$\frac{R_1}{R_2} + jwCR_1 = \frac{R_3}{R_4} + \frac{jwL_1}{R_4}$, equating the real and imaginary parts from both sides of the equation

$\frac{R_1}{R_2} = \frac{R_3}{R_4}$ ------- (2) and $L_1 = CR_1R_4$ ------(3)

These are the two balance conditions of the bridge and both are independent to each other and independent of applied source frequency. Using these conditions one by one electrical components are measured by fixing other components.

Removing L_1 from its position and when inserted L_2 in the same place then the balance conditions are the same except another set of values of the electrical components i.e.

$\frac{R'_1}{R'_2} = \frac{R'_3}{R'_4}$ ------- (4) and $L_2 = C'R'_1R'_4$ ------(5)

At first L_1 and L_2 are connected in parallel, then their parallel combination is now connected in series with R_3 and the whole combination inserted in the 3^{rd} arm of the bridge. Here C and R_2 are suitable known values. First adjusting the other resistances of the bridge, minimum value of the null detector is obtained from this balance of the real components hence,

$\frac{R''_1}{R''_2} = \frac{R''_3}{R''_4}$ ------- (6), and next changing the suitable known values of C, the earlier balance can be further adjusted to get accurate balance of the imaginary parts of the whole expression of the bridge. From this one can obtained $L^* = C''R''_1 R''_4$ ------ (7), where L^* is the equivalent parallel combination of the inductances L_1 and L_2.

And the Value of L^* is given by $L^* = \frac{L_1 L_2 - M^2}{L_1 + L_2 \pm 2M}$ ------- (8), [7] Here M is the co-efficient of mutual inductance of the two inductances L_1 and L_2 and in the expression –ve sign is taken as the coupling is positive. For all the measurements, unknown resistances can be used in the form of a resistance box or 10k variable resistance pot. But for accuracy later is desirable.

Measurement of Resistance (R)

For the measurement of unknown resistance, unknown resistance may be connected in first or fourth arm position of the bridge i.e. in place of R_1 or R_4 and any one inductance is connected in series with the variable resistance R_3. At that time the capacity of the capacitor as well as coefficient of self induction (L) are known and R_2 is any suitable known value connected in parallel with C and inserted in the second arm of the bridge. Say the unknown resistance R is connected in the first arm of the bridge R_3 and R_4 are to be adjusted different ways till to get the minimum reading of the null detector. When balance condition is reached then equating the real and imaginary part of the expressions the following relations of the components can be achieved.

$\frac{R}{R_2} = \frac{R_3}{R_4}$ -------- (9) And $L = CRR_4$ -------- (10), using first relation, R can be measured.

Measurement of Capacity of the Capacitor (C)

All the values of R_1, R_2 and L are known (out of two inductors L_1 and L_2 only one known inductor is connected with R_3). The balance of the bridge is obtained by adjusting R_3 and R_4. At that time the original balance condition also satisfied i.e. $\frac{R_1}{R_2} = \frac{R_3}{R_4}$ and $L = CR_1R_4$

From the first relation, only $\frac{R_1}{R_2}$ and $\frac{R_3}{R_4}$ ratios are accurately measured and knowing the accurate value of R_4, using the second condition, the capacity of the capacitor can be measured.

Measurement of co-efficient of Self Inductance (L)

For the case of measurement of the co-efficient of self inductance, one inductance (unknown value) is connected in series with R_3 and the values of the capacitor (C) as well as the value of resistance R_2 is known. R_2 is any suitable value connected in parallel with C and connected in the second arm of the bridge. R_1, R_3 and R_4 are to be adjusted different ways until to get the minimum reading of the null detector. When balance condition is reached then also the capacitor can be adjusted further to get the balance of the imaginary part of the mathematical expressions and finally equating the real and imaginary parts of the expressions one can get,

$\frac{R_1}{R_2} = \frac{R_3}{R_4}$ and $L = CR_1R_4$, In the both expressions every parameter other than L are known . At balance the values of different resistances can be measured accurately. Hence C, R_1 and R_4 all are known, with these values and using the second condition of balance the co-efficient of self inductance (L) can be calculated accurately.

Measurement of co-efficient Mutual Inductance

First of all, co-efficient of self inductances of the two unknown inductors have to measured separately according to the process 'Measurement of co-efficient of Self Inductance (L)' discussed earlier. Hence, L_1 and L_2 are known. Now, parallel combination of two known inductances L_1 and L_2 is connected in series with R_3 and then L^* is obtained using the equation (7). And then substituting the values of L^*, L_1 and L_2 in the equation following equation

$$L^* = \frac{L_1 L_2 - M^2}{L_1 + L_2 - 2M} - - - - - 11$$

The value of M (co-efficient of mutual inductance) can be obtained by solving the differential equation. Using the equation (Which is called coupling equation) and using the standard relation of mutual inductance between two self inductances, which is $M = k\sqrt{L_1 L_2} \quad ----12$,[7] the coupling co-efficient (k) of the two induction coils can be calculated out.[7]

III. Results And Discussions

The most important observation of the bridge is that two independent balance conditions are obtained by equating real and imaginary parts of the current that flows through the circuit, both are independent of source frequency. For the measurement of resistance equation (2) is used, as it is completely free from harmonics of the A.C source and simply the condition of balance of a wheatstone bridge. Here any one R_1 or R_4 may be treated as unknown resistance. The result got from the bridge is as accurate as the results obtained by using simply wheatstone bridge with D.C source. But the bridge is suitable to measure moderate values of the resistance, otherwise the sensitivity spoiled. It is not suitable for very high or very low resistances. Though mathematically equation (3) can also be used for the measurement of unknown resistance when L ,C and one out of R_1 or R_4 are known but due to presence of harmonics of the A.C source and some self –capacitance of the induction coil, accurate result may not be achieved. For the measurement of the capacity of the capacitor and the co-efficient of self inductance, equation (3) is used one by one but balance condition of real part is very important to get the actual results of R_1 and R_4 of the equation (2). It is also observed that with the help of the process very near to the accurate values of C and L can be obtained and for any types of variation of R_1 and R_4 though accordingly value of R_3 would be changed. With the help of the process, co-efficient of the mutual inductance can be calculated using the equation(11) between two induction coils, but when the coils are at fixed position, not possible to measure the co-efficient of mutual inductance at their various geometrical orientations. In addition to that the co-efficient of coupling can be calculated between two coils L_1 and L_2 and expected results are also obtained. For the measurement of co-efficient of self-inductance, mutual-inductances etc. the inductors should be used ideal i.e. resistance of the induction coils should be very small, otherwise additional resistance may be present in the balance equations. In the laboratory for the measurements of unknown resistance, capacitance, Inductance and for the calculation of co-efficient of mutual inductance, the bridge is experimentally tested several times and one set of the mean data obtained are tabled as shown below. After the obtained results, these results are also measured with digital multi-meters.

Table 1.1 *Measurement of Resistance (R)*

R_1 Unknown	R_2 in ohms	R_3 in ohms	R_4 in ohms	C in μF	L in mH	R_1 in ohms	R_1 in ohms Measured with digital multi-meter.
R_1	100	863	115	1.0	86.4	752	750
R_1	100	1156	4450	1.0	117.2	25.98	26.1
R_1	100	6010	2720	0.33	197.8	220.95	220

Table 1.2 *Measurement of Capacity of the Capacitance(C)*

C (Capacity of capacitor) Unknown	R_1 In ohms	R_2 In ohms	R_3 In ohms	R_4 In ohms	L in mH	C in μF	C in μF Measured with digital multi-meter.
C	170	100	2650	1560	86.4	0.325	0.33
C	120	100	1855	1540	86.4	0.467	0.47
C	66	100	2050	3045	197.8	0.985	1.0

Table 1.3 *Measurement of co-efficient of Self Inductance (L)*

L (Co-efficient of self inductance) unknown	R_1 In ohms	R_2 In ohms	R_3 In ohms	R_4 In ohms	C in μF	L in mH	L in mH Measured with digital multi-meter.
L	1650	100	1980	120	1.0	198.0	197.8
L	340	100	450	130	2.0	88.4	86.4
L	2385	100	2820	118	1.0	281.43	282.1
L	2043	100	660	32	1.0	65.4	66.08

Table 1.4 *Measurement of co-efficient Mutual Inductance*

M(co-efficient of mutual inductance) unknown	R_1 In ohms	R_2 In ohms	R_3 In ohms	R_4 In ohms	L^* in mH	L_1 in mH (Known)	L_2 in mH (Known)	M in mH	Co-efficient of coupling (k)
M	1800	100	574	32	57.6	86.4	198.00	121.39	0.92
M	1350	100	410	32	43.2	86.4	65.4	58.68	0.78
M	1550	100	494	32	49.6	65.4	198.00	71.96	0.44

IV. Conclusion

The bridge is suitable to measure resistance, capacity of capacitance, co-efficient of self inductance as well as the co-efficient of mutual inductance between two coils but one by one by using the same bridge structure. When more than one electrical component is required to measure quickly this process is very useful. When various inductances are separately placed and have to get values separately the bridge may be useful. The bridge is very simple in construction and very less time is required to measure more than one component simultaneously. Above all, accurate values of the components can be obtained by using the bridge. For the measurement of wide range of unknown components wide range of values of known components should be used. For the value of co-efficient of coupling the distance and the orientation of the two coils provides expected results. The bridge can be used to study the measurement of the components in laboratory as well as for the communication system and in electronic circuits. For the precise value of the components high quality components are required like ideal inductance and capacitance. For all the measurements, the process is suitable for moderate values of the electrical components.

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References

[1] S.Prakash, *Electricity and Magnetism.* Meerut, India, Pragati Prakasan, 2016.
[2] K.K.Tewari, *Electricity and Magnetism*, New Delhi, India, S, Chand & Company Ltd. 2011
[3] U.Sinha, *Electrical and Electronics Measurements and Instrumentation*, Reprint 1992, pp. 144-164.
[4] R, K. Rajput, *Electrical Measurement and Measuring Instrument*, Edition 2008, pp. 505-536.
[5] Ms, Shrutika ,K Adu, S,Ahivwar, G, Ramalakshimi, *Measurement of unknown Inductance and Capacitance by A.C Bridge* ,IJEER Vol.3,Issue 3.PP(181-184) September 2015.
[6] C,P, Boner, *The Measurement of Capacitance and Inductance in terms of frequency and at Radio frequency,* AIP Review of Scientific Instruments ,December 2004.
[7] B.Ghosh, *Foundations of Electricity and Magnetism (Kolkata, India, Books and Allids (P) Ltd, 2nd Edition. 2009*

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